

Description

[PIXEL STRUCTURE OF DISPLAY AND DRIVING METHOD THEREOF]

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of Taiwan application serial no.92131760, filed on Nov. 13, 2003.

BACKGROUND OF INVENTION

[0002] Field of the Invention

[0003] The present invention relates to a pixel structure of a display and a driving method thereof, and more particularly to a pixel structure of a display and a driving method thereof, which compensate threshold voltages of the transistors thereof.

[0004] Description of the Related Art

[0005] Array displays include liquid crystal displays (LCD), inorganic and organic light emitting diode (LED) displays, etc. As to LCD, backlight modules, liquid crystal and thin film transistors in pixels are used to generate

images. During displaying, the backlight modules should continuously generate light for the electronic devices, such as notebooks or PDA. The operation of the displays thereof will consume substantial power. Contrary, organic LED displays uses pixels on demand for displaying and consuming less power.

- [0006] Moreover, organic LED displays also have the other advantages, such as high luminance, low power consumption, wide viewing angles, low costs, and low weight. Therefore, organic LED displays gradually have been applied to different display applications. Referring to FIG. 1, a pixel structure of the active-matrix-addressed organic LED display includes two N-type thin film transistors 110 and 120. A row selecting line 110a is adapted to turn on the thin film transistor 110, in order to apply the voltage of the data signal line 110b to the capacitor 140 for driving the thin film transistor 120 as to generate light.
- [0007] Although the active-matrix-addressed organic LED displays have the aforementioned advantages, the luminance thereof is not stable, caused by several reasons. One of them is that because the luminance of the organic LED is proportional to the current, the threshold voltage of the thin film transistor 120 shifts during a long-time opera-

tion as to cause the instability of the current flowing therethrough. Another reason is the process inconsistence of the thin film transistors within each pixel resulting in different threshold voltages. Accordingly, the light generated therefrom is not stable. In addition, the material of the organic LED is another reason causing the problem. The turn on voltage of the organic LED (OLED) will be shifted because of an operational temperature change.

- [0008] James L. Sanford and Frank R. Libsch, of IBM inc., disclosed a pixel structure of LED display, titled "TFT AMOLED Pixel Circuits and Driving Methods," in Society For Information Display (SID). Please refer to FIGs.2A and 2B. A pixel structure of a display is shown in FIG. 2A and the pixel structure includes three N-type transistors 210, 220 and 230. A gate terminal of the transistor 210 is electrically connected to a row selecting line 210a, a source terminal thereof is electrically connected to a data signal line 210b, i.e. a data signal line and a drain terminal thereof is electrically connected to the transistors 220 and 230, and to a light emitting diode 240 via a capacitor 250. A gate terminal of the transistor 220 is electrically connected to an autozero line (AZ). The capacitor 250 is disposed between the gate and source terminals of the

transistor 230 for storing the threshold voltage and the data voltage. FIG. 2B is a timing diagram of the pixel structure of the display shown in FIG. 2A.

- [0009] The driving time of the organic LED display includes three time zones. The first time zone is used to store the threshold voltage in the capacitor 250. The second time zone is used to write in data. The third time zone is used to display. The step of writing in the threshold voltage includes: maintaining the AZ signal in a high state, Vca, for storing the threshold voltage in the capacitor 250; raising the Vca to 10 V for turning on the thin film transistor 230; and lowering the Vca to 0 V for charging the capacitor 250 to the threshold voltage of the thin film transistor 230.
- [0010] Then, the Vca is 0 V and the AZ signal is in a low state so that the data is written in. If the voltage drop on the light emitting diode 240 does not change, the voltage of the capacitor 250 will be $V_{data} + V_t$, where the V_{data} means the voltage for the data and the V_t means the threshold voltage. After the data is written in, the Vca is -18 V. A current flowing through the thin film transistor 230 is proportional to $(V_{data} + V_t - V_t)^2$, i.e. $(V_{data})^2$.
- [0011] FIG. 2C is a drawing showing luminance with the data voltage V_{data} for the modified voltage follower (solid) and

a standard voltage follower (dashed) circuits. The line (A) represents the pixel structure of FIG. 2A; the dash line (B) represents the conventional pixel structure of FIG. 1. Under the same operation of Vdata, the former has a better luminance than that of the later. FIG. 2D a drawing showing luminance difference with the data voltage Vdata for the modified voltage follower (solid) and a standard voltage follower (dashed) circuits, when the variations of the data voltage Vdata and the threshold voltage are under 2 V. The line (C) represents the pixel structure of FIG. 2A; the dash line (D) represents the prior art pixel structure of FIG. 1. When Vdata is higher than 2.5 V, the former has a worse luminance than that of the later by 20%. If Vdata is less than 2.5 V, it will be much worse. The reason of the issue is that the thin film transistor 230 induces the voltage of the light emitting diode 240 to 0 V during the writing of the data. In addition, different threshold voltages are applied to the capacitor 250 when Vca is introduced from Vt to -18 V. Therefore, the issue will affect the operation of the organic LED display.

SUMMARY OF INVENTION

[0012] Therefore, the present invention discloses a pixel structure of a display and a driving method thereof, which are

easier than those of prior art and compensate the threshold voltage of the thin film transistors.

- [0013] To achieve the object described above, the present invention discloses a pixel structure of a display, which comprises: a switching transistor, a driving transistor, a first capacitor, a light emitting diode and a reset transistor. A gate terminal of the switching transistor is electrically connected to a scan line, and a source terminal thereof is electrically connected to a signal line. A gate terminal of the driving transistor is electrically connected to a drain terminal of the switching transistor. The first capacitor is disposed between the gate terminal of the driving transistor and a source terminal thereof. The light emitting diode has a first terminal electrically connected to a operational voltage, and a second terminal electrically connected to a drain terminal of the driving transistor. A gate terminal of the reset transistor is electrically connected to an autozero, a drain terminal is electrically connected to the driving transistor, and a source terminal electrically connected to a ground voltage.
- [0014] As to the pixel structure described above, the driving method thereof comprises: turning on the switching transistor at a threshold voltage writing timing, then turning

off the reset transistor and applying a start voltage to the gate terminal of the driving transistor; lowering the operational voltage to a low voltage at an data writing timing for turning off the light emitting diode, applying an data voltage to the gate terminal of the driving transistor; and turning off the switching transistor after the data writing timing, raising the operational voltage to a high voltage, turning on the reset transistor for driving the light emitting diode.

- [0015] As to the driving method described above, the step of turning on the switching transistor is by inputting a scan voltage via the scan line. The start voltage and the data voltage are applied to the gate terminal of the driving transistor via the signal line.
- [0016] In the exemplary embodiment, the reset transistor is turned off after a delay time, when the switching transistor is turned on by the scanning voltage via the scan line; and the delay time is determined by a time of tuning on the switching transistor.
- [0017] As to the driving method described above, the gate terminal of the reset transistor is electrically connected to an autozero line. The first terminal of the light emitting diode is an anode, and the second terminal thereof is a cathode.

[0018] To achieve the object described above, the present invention discloses another pixel structure of a display, which comprises: a switching transistor, a driving transistor, a first capacitor, a light emitting diode and a reset transistor. A gate terminal of the switching transistor is electrically connected to a scan line, and a source terminal thereof is electrically connected to a signal line. A gate terminal of the driving transistor is electrically connected to a drain terminal of the switching transistor. The first capacitor is disposed between the gate terminal of the driving transistor and a source terminal thereof. The light emitting diode has a second terminal electrically connected to a ground voltage, and a first terminal electrically connected to a source terminal of the driving transistor. A gate terminal of the reset transistor is electrically connected to an autozero, a source terminal is electrically connected to the driving transistor, and a drain terminal electrically connected to an operational voltage.

[0019] As to the pixel structure described above, the driving method thereof comprises: turning on the switching transistor at a threshold voltage writing timing, then raising the ground voltage to a high voltage for turning off the light emitting diode and applying a start voltage to the

gate terminal of the driving transistor; turning off the reset transistor at an data writing timing for turning off the light emitting diode, and applying an data voltage to the gate terminal of the driving transistor; and turning off the switching transistor after the data writing timing, lowering the ground voltage to a low voltage for driving the light emitting diode, and turning on the reset transistor.

- [0020] As to the driving method described above, the step of turning on the switching transistor is by inputting a scan voltage via the scan line. The start voltage and the data voltage are applied to the gate terminal of the driving transistror via the signal line.
- [0021] In the exemplary embodiment, the ground voltage is raised to the high voltage after a delay time, when the switching transistor is turned on by the scanning voltage via the scan line; and the delay time is determined by a time of tuning on the switching transistor.
- [0022] In the exemplary embodiment, the gate terminal of the reset transistor is electrically connected to an autozero line.
- [0023] As to the pixel structure described above, the switching transistor, the driving transistor and the reset transistor are thin film transistors.

- [0024] As to the pixel structure described above, the switching transistor, the driving transistor and the reset transistor are made from poly-silicon or amorphous silicon.
- [0025] As to the pixel structure described above, the first terminal of the light emitting diode is an anode, and the second terminal thereof is a cathode.
- [0026] As to the pixel structure described above, the light emitting diode is made from an organic material.
- [0027] As to the driving method described above, the start voltage V_o is applied to the gate terminal of the driving transistor so that a gate voltage thereof is V_o ; and a source voltage is $V_o - V_T$, wherein the V_T is a threshold voltage of the driving transistor.
- [0028] As to the driving method described above, the data voltage V_{data} is applied to the gate terminal of the driving transistor so that a voltage drop on the first capacitor is $V_{data} - (V_o - V_T + \Delta V_{data})$, wherein the $\Delta V_{data} = K(V_{data} - V_o)$. The driving current of the light emitting diode is proportional to $(V_{data} - V_o - \Delta V_{data})^2$.
- [0029] As to the driving method described above, $K = C_s / C_{total}$, C_s represents a capacitance of the first capacitor, and C_{total} is a sum of capacitances on the source terminal of the driving transistor.

- [0030] In the exemplary embodiment, the pixel structure further comprises a second capacitor disposed between the source terminal and the drain terminal of the reset transistor for adjusting the K. In another embodiment, the second capacitor is disposed between the first and the second terminals of the light emitting diode.
- [0031] In order to make the aforementioned and other objects, features and advantages of the present invention understandable, a preferred embodiment accompanied with figures is described in detail below.

BRIEF DESCRIPTION OF DRAWINGS

- [0032] FIG. 1 shows a conventional pixel structure of an organic LED display includes two N-type thin film transistors.
- [0033] FIG. 2A shows another conventional pixel structure of an organic LED display.
- [0034] FIG. 2B shows a timing diagram of the pixel structure of the display shown in FIG. 2A.
- [0035] FIG. 2C shows luminance with the data voltage V_{data} for the modified voltage follower (solid) and a standard voltage follower (dashed) circuits.
- [0036] FIG. 2D shows luminance difference with the data voltage V_{data} for the modified voltage follower (solid) and a standard voltage follower (dashed) circuits, when the varia-

tions of the data voltage V_{data} and the threshold voltage are under 2 V.

- [0037] FIG. 3A shows a preferred embodiment of a pixel structure of a display.
- [0038] FIG. 3B shows a timing diagram related to a driving method of the pixel structure as shown in FIG.3A.
- [0039] FIG. 4A shows another preferred embodiment of a pixel structure of a display.
- [0040] FIG. 4B shows another timing diagram related to a driving method of the pixel structure as shown in FIG.4A.

DETAILED DESCRIPTION

- [0041] Following are the descriptions of the present to interpret the feature thereof. The scope of the present invention, however, is not limited thereto.
- [0042] The present invention discloses a pixel structure of a display and a driving method thereof for compensating the threshold voltage of the thin film transistors.
- [0043] FIG. 3A shows a preferred embodiment of a pixel structure of a display. FIG. 3B shows a timing diagram related to a driving method of a preferred embodiment of the present invention. The pixel structure shown in FIG.3A includes three N-type transistors: a switch transistor 310, a driving transistor 320 and a reset transistor 330.

[0044] A gate terminal of the switching transistor 310 is electrically connected to a scan line 310a, and a source terminal thereof is electrically connected to a signal line 310b, i.e. a data signal line. A drain terminal thereof is electrically connected to the driving transistor 320 and electrically connected to the reset transistor 330 via a capacitor 340. A gate terminal of the reset transistor 330 is electrically connected to an autozero line AZ, a drain terminal thereof is electrically connected to the driving transistor 320, and a source terminal is electrically connected to a ground voltage V_{SS} . The anode of the light emitting diode 350 is electrically connected to an operational voltage V_{DD} , and the cathode thereof is electrically connected to the drain terminal of the driving transistor 320. The capacitor 340 is disposed between the gate and source terminals of the driving transistor 320 for storing the threshold voltage and the data voltage.

[0045] In a preferred embodiment, the pixel structure of the present invention includes thin film transistors and made from, such as poly-silicon or amorphous silicon. In the embodiment, the light emitting diode 350 can be an organic light emitting diode. However, the present invention is not limited thereto. Any other types of transistors or

light emitting diodes can also be applied in the present invention. In addition to the N-type transistors, the present invention also can use P-type transistors by simply modifying the design of the driving part.

[0046] FIG. 3B is a timing diagram related to a driving method of the preferred embodiment of the pixel structure of the display shown in FIG. 3A. A threshold voltage (V_T) is applied to the capacitor 340 at a threshold voltage writing timing. The data signal is applied to the pixel at a data writing timing. The light emitting diode 350 then illuminates according to the data signal. At the beginning of the V_T writing timing, the scanning signal voltage V_{scan} on the scan line 310a is raised to a high voltage for turning on the switching transistor 310. The V_{AZ} on the AZ line is lowered to a low voltage for turning off the reset transistor 330. The rise of the V_{AZ} and the lowering of the V_{scan} can occur simultaneously or the rise of the V_{AZ} delays for a period of time as indicated by the dash line for synchronization with the switching transistor 310. The delay time depends on a time from the raising of the V_{scan} to the turning on of the switching transistor 310. Then, a start voltage V_0 is applied to the signal line 310b. The current passes through the driving transistor 320 is zero. The

voltage level V_G of the gate terminal of the driving transistor 320 is charged to V_o , and the voltage level V_s of the source terminal is charged to $V_o - V_T$.

[0047] At the data writing timing, the operational voltage V_{DD} is in a low state for turning off the light emitting diode 350, that is, no current is passed through the terminals of the operational voltage V_{DD} and the ground V_{SS} . The data voltage V_{data} from the signal line 310b is electrically connected to the source terminal of the switching transistor 310. The voltage drop on the capacitor 340 is $V_{data} - (V_o - V_T + \Delta V_{data})$, where $\Delta V_{data} = K(V_{data} - V_o)$ and $K = C_s / C_{total}$, C_s represents the capacitance of the capacitor 340, and C_{total} represents a sum of capacitances on the source terminal of the driving transistor 320. Moreover, in an alternative embodiment of the present invention, another capacitor 360 can be disposed between the source and drain terminals of the reset transistor 330 for changing the C_{total} and adjusting the K in response with the design requirement.

[0048] After the data writing time, the switching transistor 310 is turned off. The operational voltage V_{DD} is raised to a high voltage for driving the light emitting diode 350, the V_{AZ} also is in a high state for turning on the reset transistor

330. After the switching transistor 310 is turned off, the driving transistor 320 is floating. Therefore, the voltage drop on the capacitor 340 is still $V_{data} - (V_o - V_T + \Delta V_{data})$. Because the driving transistor 320 is operated in a saturation region, the current is proportional to the $[V_{data} - (V_o - V_T + \Delta V_{data}) - V_T]^2$, or $(V_{data} - V_o - \Delta V_{data})^2$. Accordingly, the current of the light emitting diode 350 is irrelevant to the V_T of the driving transistor 320. Therefore, the operation of the pixel structure of the display does not depend on the V_T and is affected thereby.

[0049] FIG. 4A shows another preferred embodiment of a pixel structure of a display. FIG. 4B shows a timing diagram related to a driving method of another preferred embodiment of the present invention. The pixel structure shown in FIG. 4A includes three N-type transistors: a switch transistor 410, a driving transistor 420 and a reset transistor 430. A gate terminal of the switching transistor 410 is electrically connected to a scan line 410a, and a source terminal thereof is electrically connected to a signal line 410b, i.e. a data signal line. A drain terminal thereof is electrically connected to the driving transistor 420 and electrically connected to the anode of the light emitting diode 450 via the capacitor 440. A gate terminal of the

reset transistor 430 is electrically connected to an autozero line AZ, a drain terminal thereof is electrically connected to the operational voltage V_{DD} , and a source terminal is electrically connected to the driving transistor 420. A cathode of the light emitting diode 450 is electrically connected to an ground voltage V_{SS} . The source terminal of the driving transistor 420 is electrically connected to the anode of the light emitting diode 450. The capacitor 440 is disposed between the gate and source terminals of the driving transistor 420 for storing the threshold voltage and the data voltage.

- [0050] In a preferred embodiment, the pixel structure of the present invention is composed of thin film transistors and made from, such as poly-silicon or amorphous silicon. In the embodiment, the light emitting diode 450 can be an organic light emitting diode. However, the present invention is not limited thereto. Any other types of transistors or light emitting diodes can also be applied thereto. In addition to the N-type transistors, the present invention also can use P-type transistors, by simply modifying the design of the driving part.
- [0051] FIG. 4B is a timing diagram related to a driving method of the preferred embodiment of the pixel structure of the

display shown in FIG. 4A. A threshold voltage (V_T) is applied to the capacitor 440 at a threshold voltage writing timing. The data signal is applied to the pixel at a data writing timing. The light emitting diode 450 then illuminates according to the data signal.

- [0052] At the beginning of the V_T writing timing, the scanning signal voltage V_{scan} on the scan line 410a is raised from a low voltage level to a high voltage level for turning on the switching transistor 410. The V_{ss} rises to a high voltage level. The rise of the V_{ss} and the raise of the V_{scan} can occur simultaneously or the rise of the V_{ss} delays for a period of time as indicated by the dash line for synchronization with the switching transistor 410. The delay time depends on a time from the raising of the V_{scan} to the turning on of the switching transistor 410. A start voltage V_0 is then applied to the signal line 410b. The current passes through the driving transistor 420 is zero. In the driving transistor 420, the voltage level V_G of the gate terminal is charged to V_0 , and the voltage level V_S of the source terminal is charged to $V_0 - V_T$.
- [0053] At the data writing timing, the V_{AZ} on the AZ line is lowered to a low voltage for turning off the reset transistor 430 and avoiding any current flowing through the termi-

nals of the V_{DD} and the V_{SS} . A data voltage V_{data} is applied to the signal line 410b, which is electrically connected to the source terminal of the switching transistor 410. The voltage drop on the capacitor 440 is $V_{data} - (V_o - V_T + \Delta V_{data})$, wherein $\Delta V_{data} = K(V_{data} - V_o)$ and $K = C_s/C_{total}$, C_s represents the capacitance of the capacitor 440, and C_{total} represents a sum of capacitances on the source terminal of the driving transistor 420. Moreover, in an alternative embodiment, another capacitor 460 can be disposed between the anode and cathode of the light emitting diode 450 for changing the C_{total} and adjusting the K in response with the design requirement.

- [0054] After the data writing time, the switching transistor 410 is turned off. The V_{AZ} is raised to a high voltage for turning on the reset transistor 430, and the V_{SS} is lowered to a low voltage for driving the light emitting diode 450. After the switching transistor 410 is turned off, the gate terminal of the driving transistor 420 is floating. Therefore, the voltage drop on the capacitor 440 is still $V_{data} - (V_o - V_T + \Delta V_{data})$. Because the driving transistor 420 is in saturation region, the current is proportional to the $[V_{data} - (V_o - V_T + \Delta V_{data}) - V_T]^2$, or $(V_{data} - V_o - \Delta V_{data})^2$. Accordingly, the current of the light emitting diode 450 is ir-

relevant to the V_T of the driving transistor 420. Therefore, the operation of the pixel structure of the display does not depend on the V_T and is affected thereby.

- [0055] Accordingly, the present invention discloses a pixel structure of a display and a driving method thereof, which are easier than those of prior art and compensate the threshold voltage of the thin film transistors.
- [0056] Although the present invention has been described in terms of exemplary embodiments, it is not limited thereto. Rather, the appended claims should be construed broadly to include other variants and embodiments of the invention which may be made by those skilled in the field of this art without departing from the scope and range of equivalents of the invention.